712CD

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From Field Data to Reliability Optimization, a Navy LCAC Application

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From Field Data to Reliability Optimization:
Navy LCAC Application

MORS Symposium
June 2007

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Systems Sustainment and Readiness Technologies
Sandia National Laboratories

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Outline

- **Navy's Needs**
- **Approach: Overview & Details**
  - **1) Analyze Field Data**
  - **2) Create Baseline Model**
  - **3) Optimize Over Improvements**
- **Summary**

***Disclaimer:** Data and logic used in this presentation are for example purposes only. They are not, and should not be treated as, real LCAC data and information.*

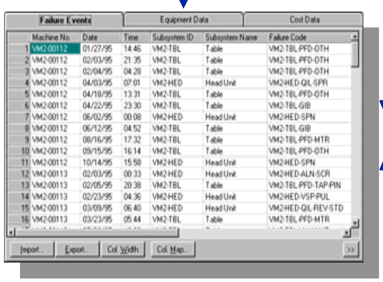
Navy Needs

- **Navy needs "a model to perform analyses of current and future LCAC maintenance and support operations"**
  - **How will funding changes (up or down) impact fleet readiness?**
  - **How will planned upgrades improve fleet readiness?**
- **Navy will run what-if scenarios to optimize over**
  - **Budget**
  - **Maintenance**
  - **Operations & Support**

Translate $$$ into Readiness

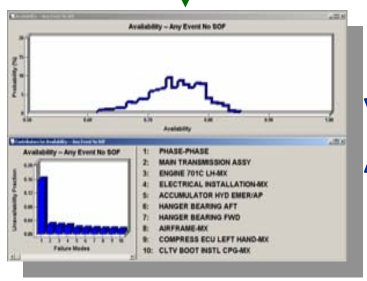
Approach – Overview

Maintenance Records
(Unscheduled, Inspections, ...)
Cost Information
Operating Hours



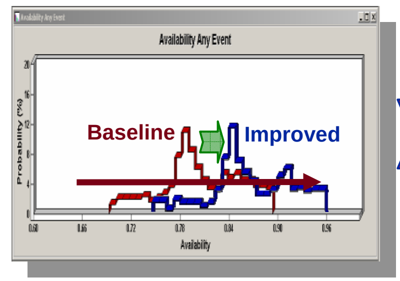
Analyze Field Data

Craft Configurations
Updated Data



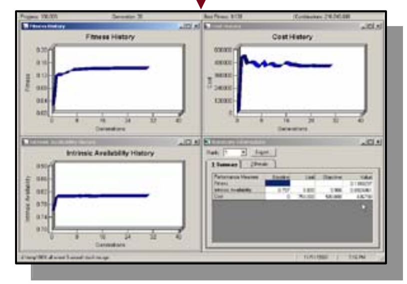
Create Baseline Model

Planned Upgrades



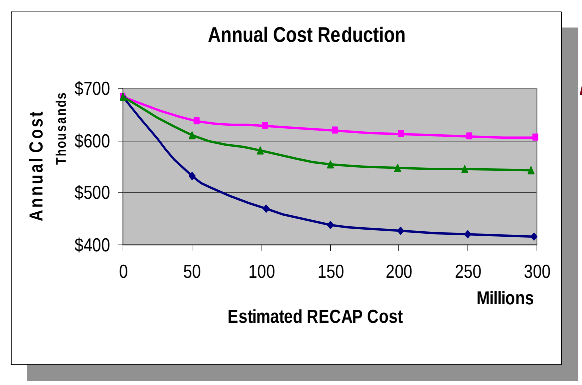
Predict Impact

Performance Objectives
Constraints/ Requirements

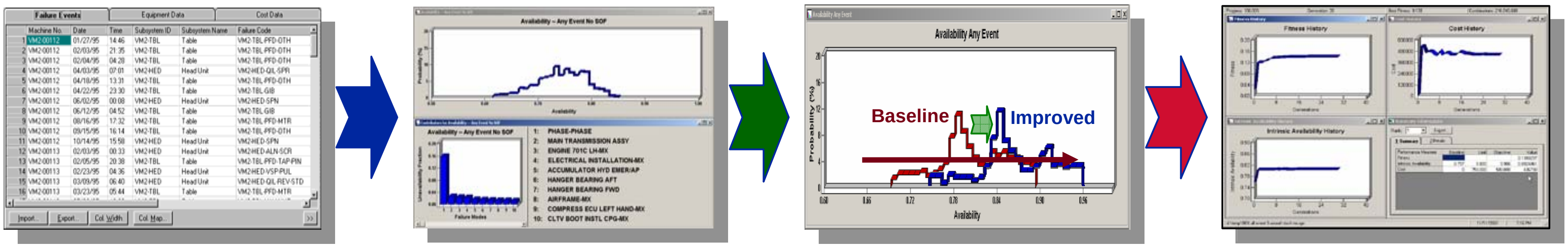


Optimize Over Improvements

RESULTS & DECISIONS



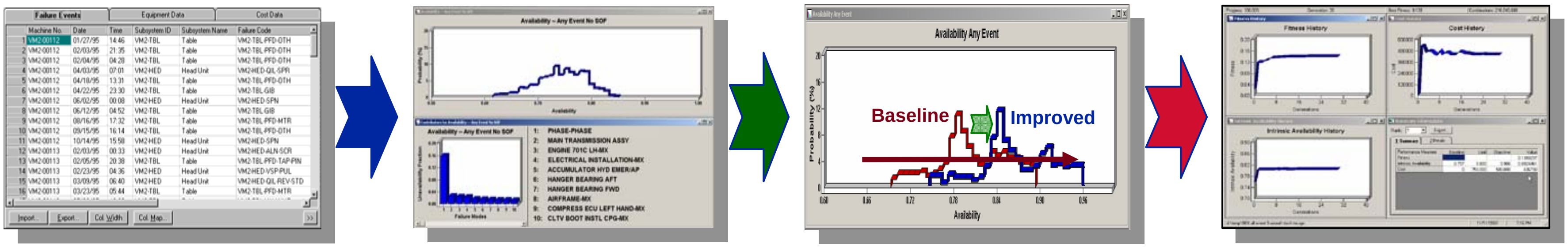
Approach – Overview



Analyze Field Data | **Create Baseline Model** | **Predict Impact** | **Optimize Over Improvements**

- ## Analyze Field Data
  - Investigate existing failure & maintenance data sources
  - Recommend improved data collection process
- ## Create Baseline Model
  - Populate with existing failure & maintenance data (updated data, if necessary)
  - Capture component redundancy for various craft configurations
  - Analyze current system performance (Readiness, Annual Costs, …)

Approach - Overview



Analyze Field Data	**Create Baseline Model**	**Predict Impact**	**Optimize Over Improvements**

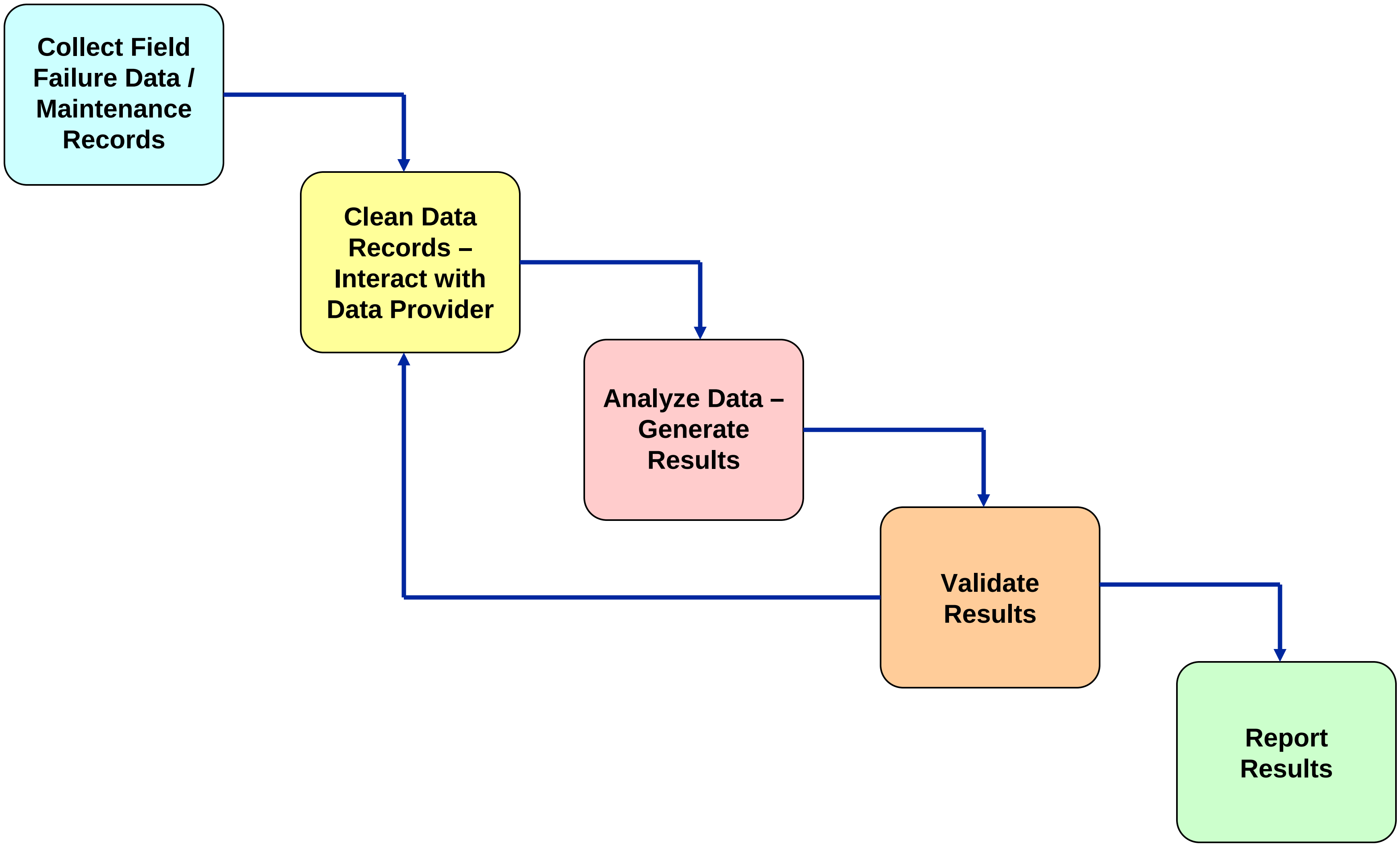
- **Predict Impact (optional)**
  - **Predict impacts of current planned changes in maintenance, supply, and budget policies**
  - **Evaluate other cost and availability drivers identified by the baseline model**
- **Optimize Over Improvements (“best bang for the buck”)**
  - **Examine improvement options**
  - **Optimize to select best improvements**
  - **Incorporate user-defined constraints**

Analyze Field Data

- **Goal**
  - **Assessment of "As-Is" Performance**
- **Inputs**
  - **Basic Maintenance and Logistical Data**
    - **Machine ID**
    - **Failure Mode: Code & Name**
    - **Failure Date & Time**
    - **Total Downtime**
    - **Event Type (Failure, Preventative Maintenance, …)**
    - **Costs**
    - **Operating Hours**

Assigned Names	Linked	Pro-Opta Fields
Code	<==>	FailureCode
Date	<==>	FailureDate
Name	<==>	FailureName
Time	<==>	FailureTime
Machine ID	<==>	MachineID
Downtime	<==>	TotalDowntime

Analyze Field Data: Data Analysis Process



Analyze Field Data

- **Description**
  - **Calculates "Nominal" Output**
    - **Calculated directly from data**
    - **Example Questions Answered:**
      - **What was our largest Downtime driver last year?**
      - **Which craft had the best Availability this quarter?**
  - **Calculates "Statistical" Output**
    - **Uses randomness from raw data to provide distributional assessments**
      - **Information about variability is gathered from the deterministic historic data**
    - **Example Question Answered:**
      - **Which failure modes contributed the most to variability in Maintenance Cost over the past 2 years?**

Analyze Field Data: Sample Output

- **Availability: Numerical Summary**
  - **Nominal Value, Mean, Median, Percentiles, Standard Deviation**

Readiness (Operational Availability)

Summary Statistics

Statistic	Availability
Mean	0.61088
Nominal	0.62979
Std. Deviation	0.1493
1st Percentile	0.17621
5th Percentile	0.30478
10th Percentile	0.38984
20th Percentile	0.50066
30th Percentile	0.55182
40th Percentile	0.61445
50th Percentile	0.64925
60th Percentile	0.68435
70th Percentile	0.71263
80th Percentile	0.73729
90th Percentile	0.76401
95th Percentile	0.78787
99th Percentile	0.80895

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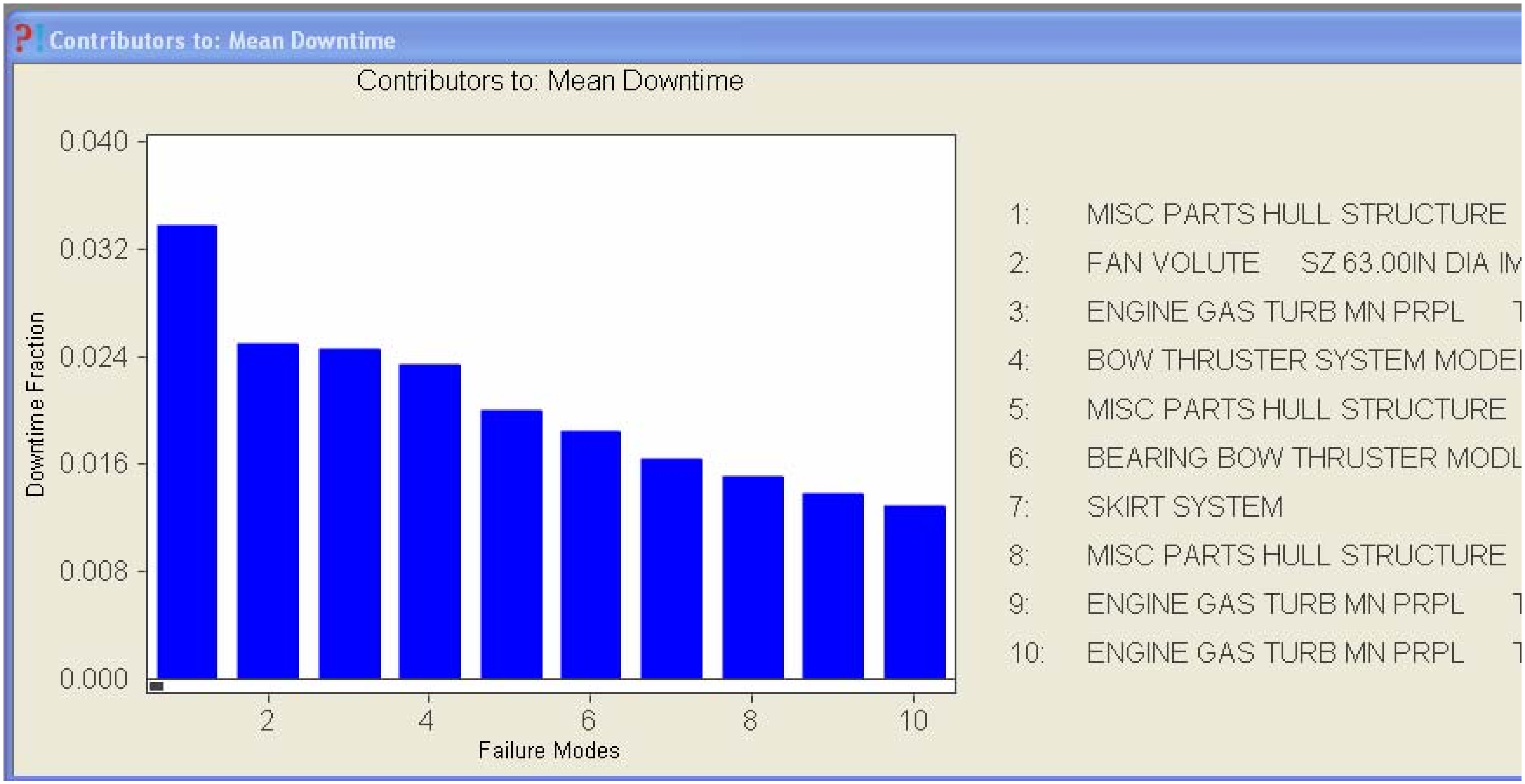
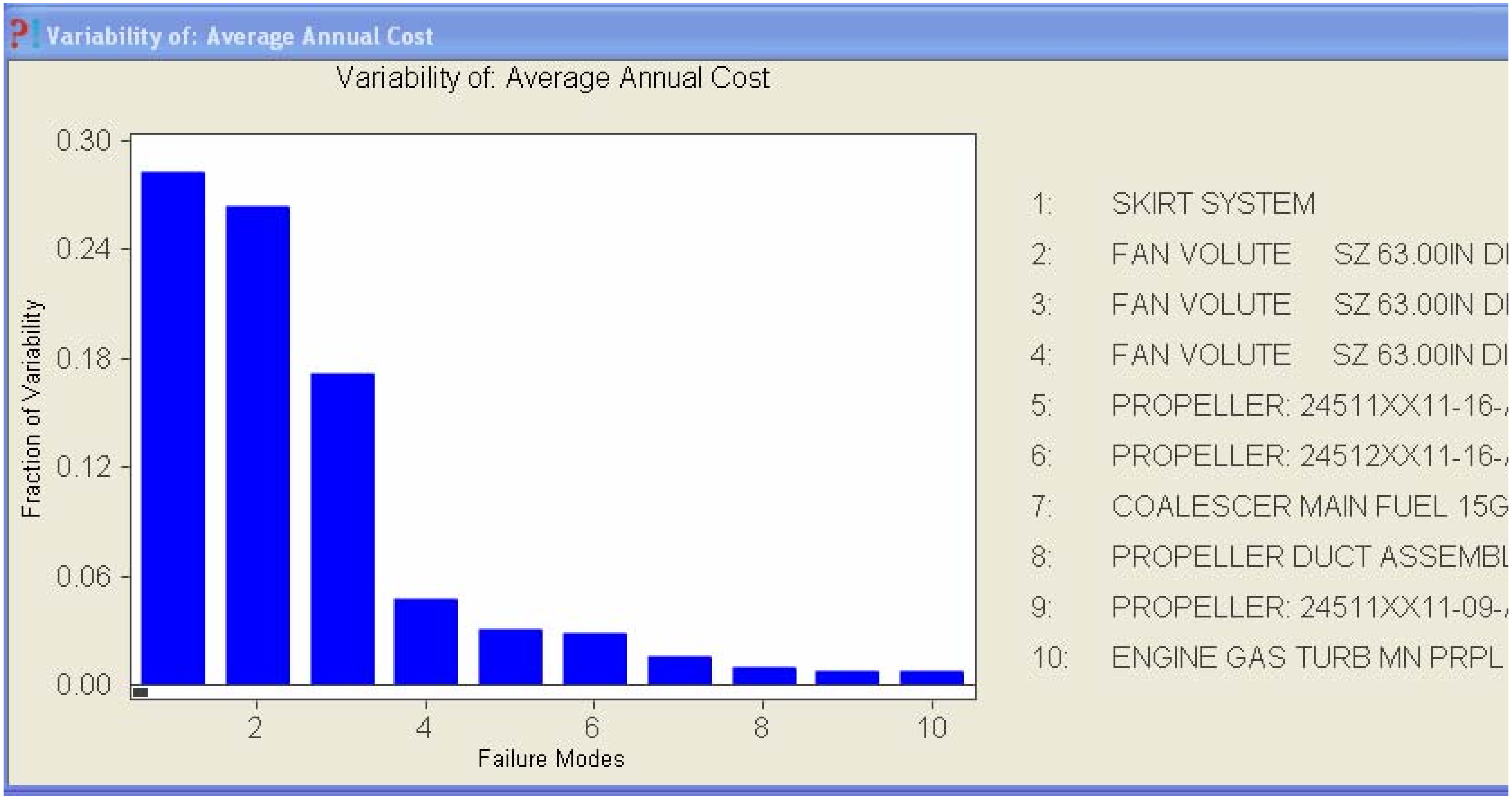
Analyze Field Data: Sample Output

- **Downtime: Failure Mode Pareto**
  - **Failure Types Driving Downtime**



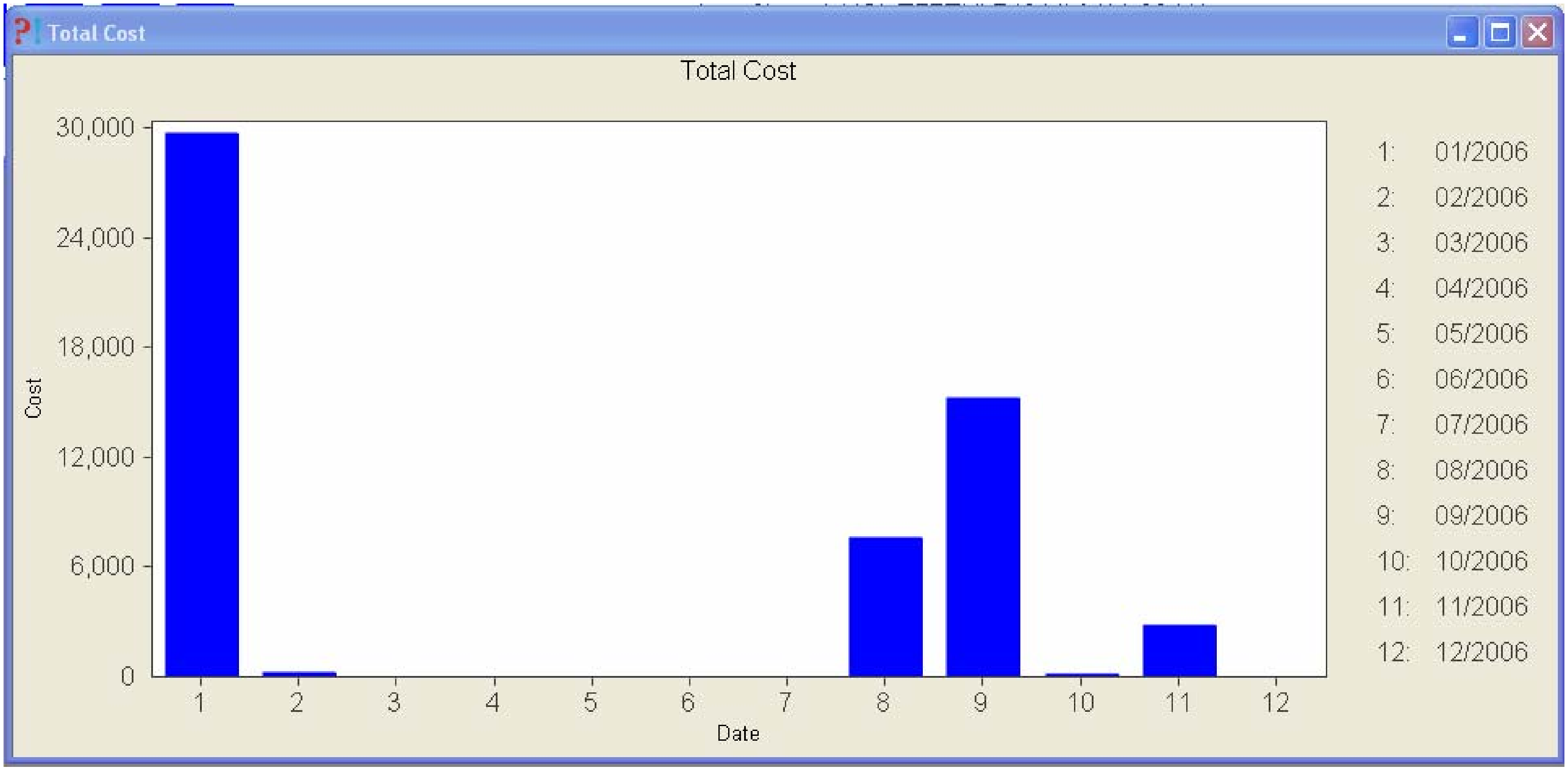
Analyze Field Data: Sample Output

- **Cost: Variability Quantification**
  - **Failure Types Driving Cost Variability**



Analyze Field Data: Sample Output

- **Cost: Craft Details**
  - **Monthly Costs for a single Craft**



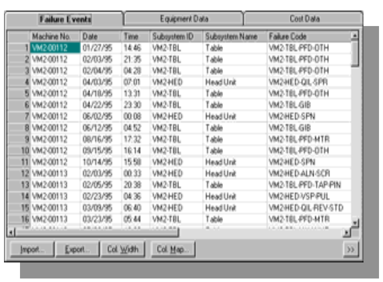
Analyze Field Data

- **Output Metrics/Values**
  - **Availability**
  - **MTBF**
  - **Downtime**
  - **Cost**
  - *Both Built-in and User-defined version of the above*
    - *Example: Readiness*
  - **Failure Mode Summary**
    - **Downtime Distributions**
    - **Failure Rate Distributions**
- **Output Types/Formats**
  - **Numerical Summary**
    - **Nominal Value**
    - **Mean, Median, Percentiles, Standard Deviation**
  - **Paretos of Failure Modes with the most impact**
  - **Variability Quantification**
  - **Data by Fleet or by Craft**

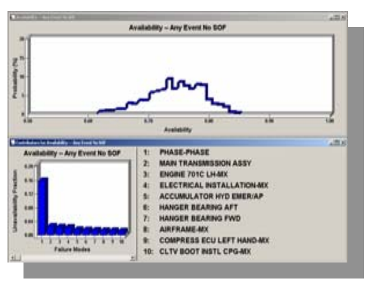
Create Baseline Model

- **Goals**
  - Create sophisticated model of fleet and craft configurations
  - Ability to assess planned component & design changes
    - Ability to answer “What If …” questions
  - Update Failure Mode Data, if necessary

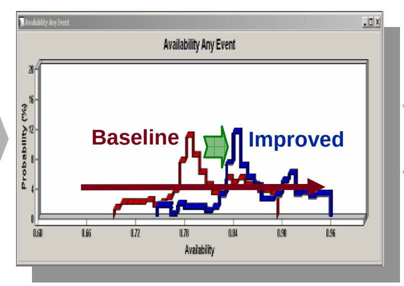
- **Inputs**
  - Failure Modes: Failure Rate, Downtime, and Cost Distributions
    - Combination of field data and info from other sources
  - Craft configurations with component redundancy
  - Sub-system hierarchy



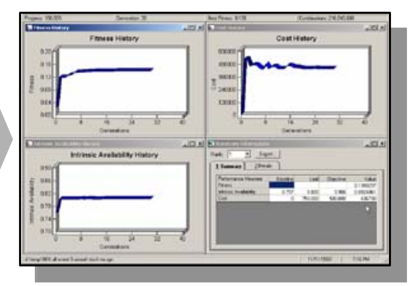
Analyze Field Data



Create Baseline Model



Predict Impact



Optimize Over Improvements

Create Baseline Model

- **Description**
  - **Fault Tree solver**
  - **Capability to model a family of Fault Trees**
    - **Multiple Configurations**
    - **Some shared failure modes**
    - **Different redundancy structures**

Fault Tree	Failure Mode ID	Event Name
LCAC IS NON-MISSION CAPABLE		
HULL MALFUNCTION		
10000XX1	10000XX1	HULL STRUCTURE
11911XX1	11911XX1	SKIRT SYSTEM
RADIO MALFUNCTION		
44151XX01	44151XX01	RADIO - A
44151XX02	44151XX02	RADIO - B
44151XX03	44151XX03	RADIO - C
44151XX04	44151XX04	RADIO - D

Fault Tree	Failure Mode ID	Event Name
LCAC IS NON-MISSION CAPABLE		
HULL MALFUNCTION		
10000XX1	10000XX1	HULL STRUCTURE
11911XX1D	11911XX1D	DEEP SKIRT SYSTEM
RADIO MALFUNCTION		
44151XX01	44151XX01	RADIO - A
44151XX02	44151XX02	RADIO - B
44151XX03	44151XX03	RADIO - C
44151XX04	44151XX04	RADIO - D

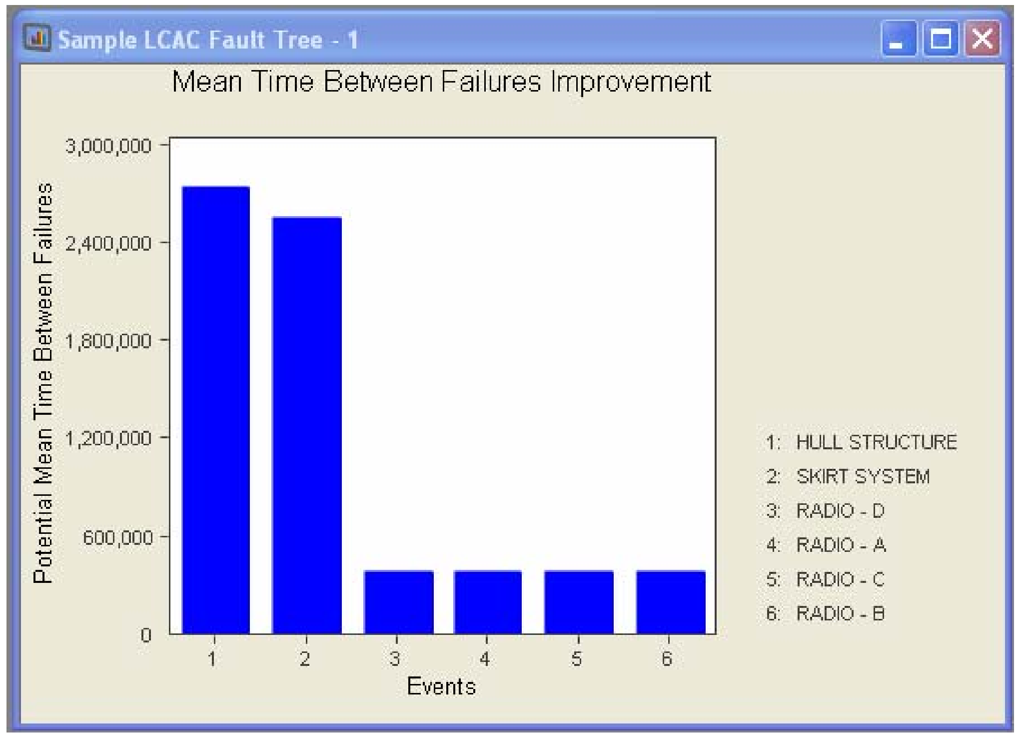
Create Baseline Model

- **Outputs**
  - **A set of output for each Configuration**
  - ***Very similar to "Analyze Field Data" output***

Sample LCAC Fault Tree - ...

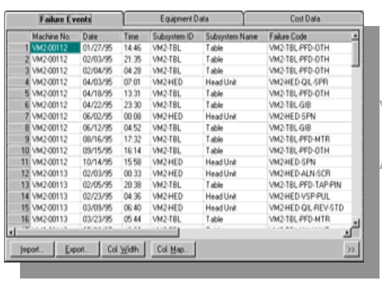
Summary Statistics
Sample LCAC Fault Tree - 1: Annual Downtime

Statistic	Hours
Mean	2.8129
Nominal	124.6461
Std. Deviation	2.8406
1st Percentile	0.0286
5th Percentile	0.1431
10th Percentile	0.2985
20th Percentile	0.6278
30th Percentile	1.0007
40th Percentile	1.435
50th Percentile	1.9464
60th Percentile	2.5715
70th Percentile	3.3775
80th Percentile	4.5015
90th Percentile	6.469
95th Percentile	8.396
99th Percentile	12.8801

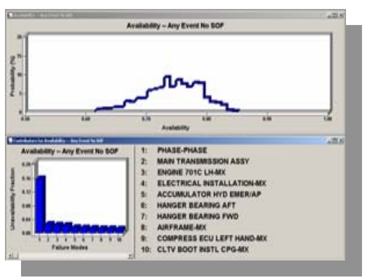


Optimize Over Improvements

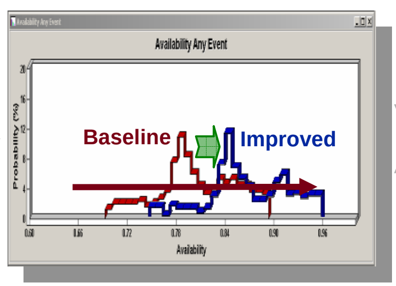
- **Goal**
  - Select Improvements for max Availability, min Costs
    - While incorporating user-defined constraints
- **Inputs**
  - Baseline Model: Single configuration OR *multiple* configurations
  - Potential Improvements
    - Benefits to Failure Rate, Downtime. Impact to Constraints.
  - Goals & Limitations
    - Acceptance criteria for “good” solutions
    - User-Defined constraints (Development Cost, Weight, Firepower, …)



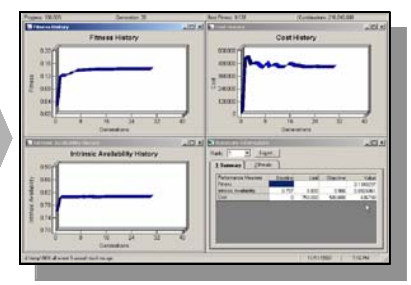
Analyze Field Data



Create Baseline Model



Predict Impact



Optimize Over Improvements

Optimize Over Improvements

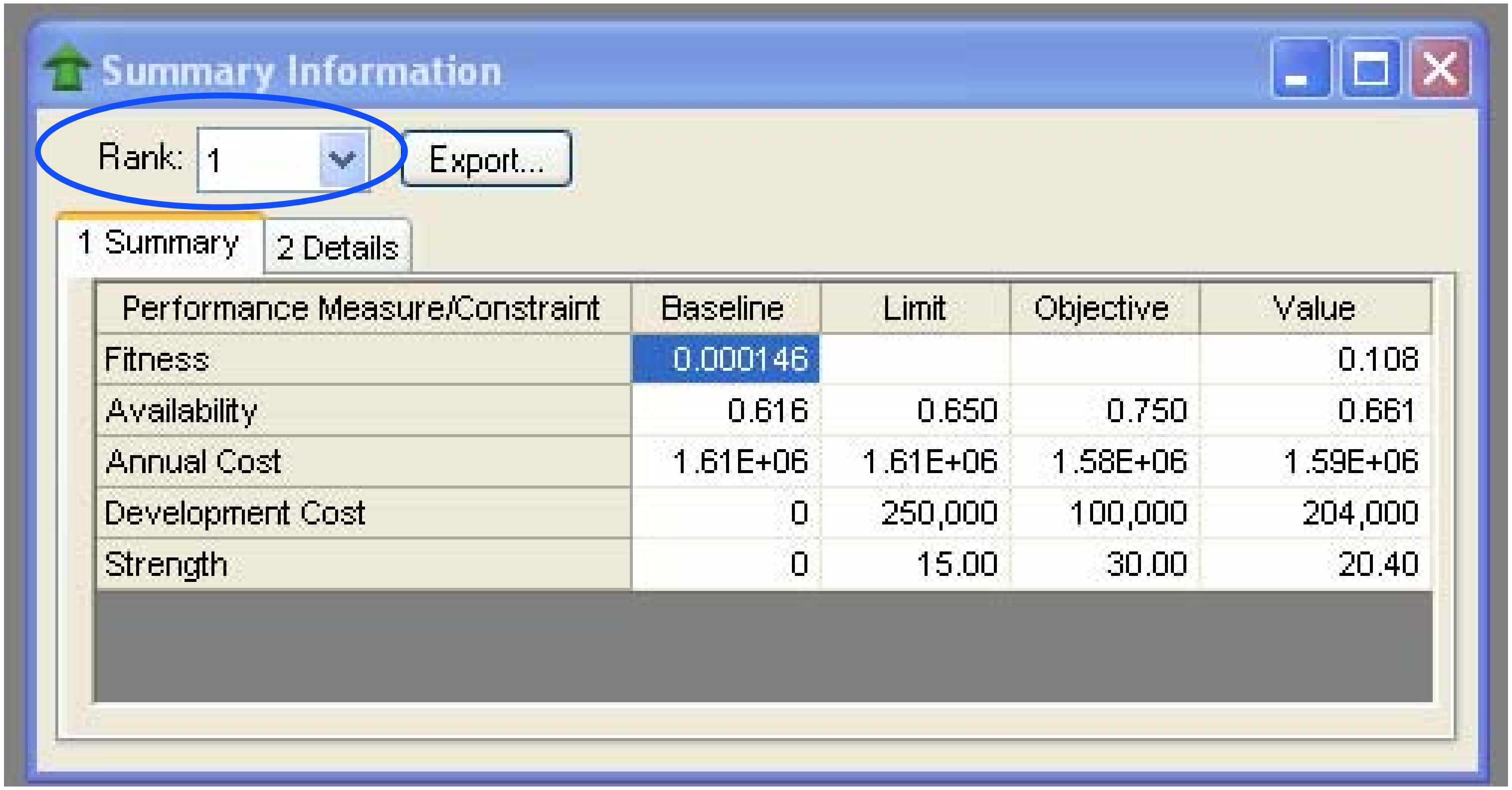
- **Description**
  - Optimization – can choose between
    - Weighted-Objective Genetic Algorithm
    - Multi-Objective Genetic Algorithm
    - Full Enumeration (no heuristic or algorithm)
  - Simultaneously Maximizes Availability, Maximizes MTBF, Minimizes Annual Cost, and/or Minimizes Annual Downtime
    - All while incorporating user-defined constraints

- **Sample Input: Improvement Tradeoffs**

Component	Observed MTBF	% MTBF Improvement	Development Cost	Weight
Skirt System	2103	10%	$30M	+500lbs
Skirt System	2103	15%	$35M	+1000lbs
Skirt System	2103	20%	$42M	+2500lbs
Skirt System	2103	25%	$59M	+4000lbs
Radio / Communications	982	5%	$3M	+0lbs
Radio / Communications	982	10%	$7M	+100lbs
Radio / Communications	982	18%	$20M	+500lbs
...	...	...	...	...

Optimize Over Improvements: Output

- **Value attained for each Performance Measurement & Constraint**
  - **Values available for top 25 solutions**



Performance Measure/Constraint	Baseline	Limit	Objective	Value
Fitness	0.000146			0.108
Availability	0.616	0.650	0.750	0.661
Annual Cost	1.61E+06	1.61E+06	1.58E+06	1.59E+06
Development Cost	0	250,000	100,000	204,000
Strength	0	15.00	30.00	20.40

Optimize Over Improvements: Output

- **Improvement Options to Implement**

Summary Information

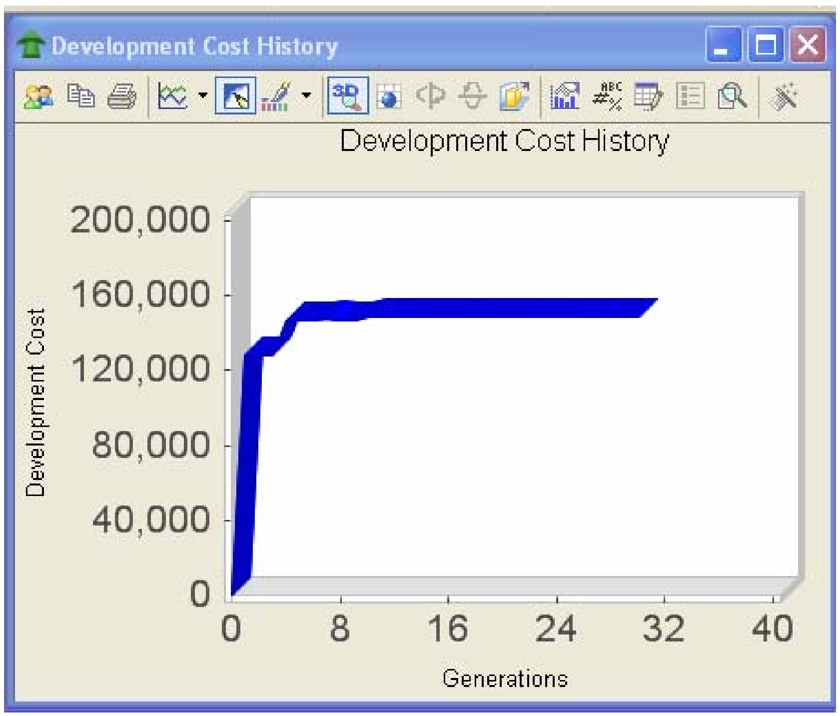
Rank: 1 Export...

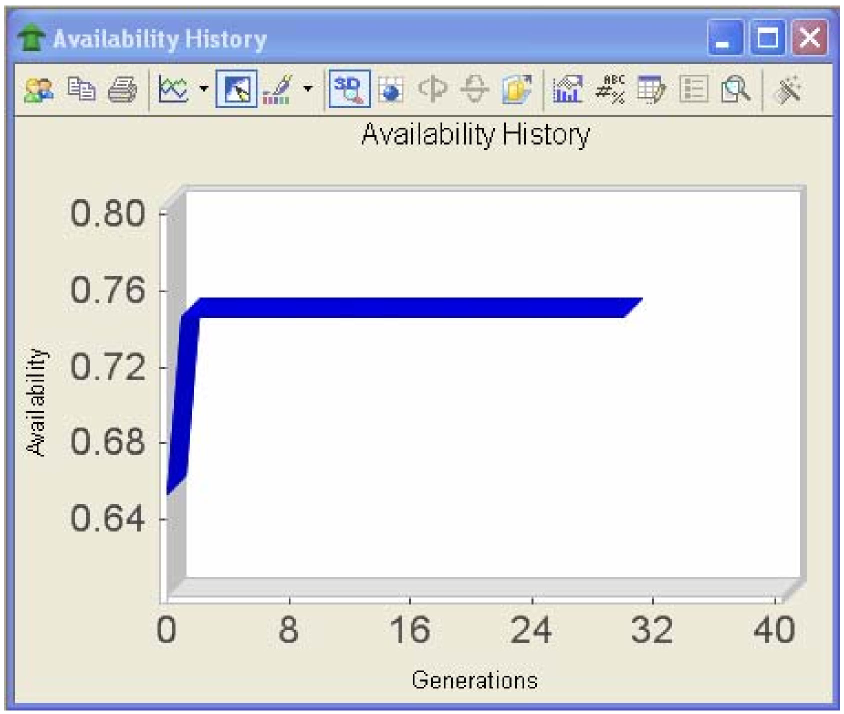
1 Summary | 2 Details

Option	Level	Development Cost	Strength
Power Supply Overhaul	0	0.00	0.00
Hull Structure Improvements	10	50,000.00	5.00
Propeller Changes	5	9,000.00	0.90
Rudder Upgrade	9	45,000.00	4.50
Scheduled Maintenance Streamline	2	100,000.00	10.00
Total		204,000.00	20.40

Optimize Over Improvements: Output

- **Graphical Histories of Optimal Solution**





Summary

- **Analyze Field Data**
  - Assess current conditions for components, craft, fleet
- **Baseline Model**
  - Understand craft design & configurations
  - Examine planned changes
    - Mix of historical field data and info from other sources
- **Optimize Over Improvements**
  - Consider multiple configurations together
  - Select best improvements for Availability, Cost, User Requirements simultaneously
  - Incorporate additional feedback and “fuzzy” constraints by selecting among top solutions